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Technology Diffusion or Capital Accumulation? An Empirical Assessment of Convergence in Manufacturing

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Abstract

In this paper I consider 28 developed and developing countries, in the period 1980-1995, and I employ the Within Group and the Generalized Method of Moments estimators to test, respectively, for Total Factor Productivity determinants and labor-productivity convergence driving forces (i.e.capital accumulation and technological catch-up) in different manufacturing sectors, identified according the technological content of their production. Moreover, I test for inter-sectoral and cross-country heterogeneity of labor productivity convergence tendencies.
My results show that technology growth rate is enhanced by technological transfer, in all manufacturing sectors and countries, and that cross-country convergence is determined by technology diffusion rather than capital accumulation. Further, I find that the rate of technological convergence appears higher in emerging economies, particularly in High Tech sectors. Finally, tertiary education seems to be relatively more important, as absorptive capability, than secondary one.

JEL Classification Code: O14, O47, L60.

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1 Introduction

A major problem in neoclassical growth theory is that the determinant of long run labour productivity growth rates, namely efficiency improvements over time, or technological change, are determined outside the model and so remain unexplained. In response to this weakness, the theory of endogenous growth emerged in the mid of 1980s. The main characteristic of 'new growth theories' is that they drop the neoclassical assumption of diminishing returns to capital, formalising an endogenous mechanism through which technical change takes places. In other words, the force that shifts out the production frontier is determined within the model and, thus, it is endogenous.

In a multicountry setting, where countries that have reached different stage of economic development interact, the endogenous mechanism that leads to technological change is identified by the *innovation-imitation* dynamics (Grossman and Helpman (1991); Barro and Sala-i-Martin (1997); Aghion and Howitt (1998)).

In particular, if the country is technologically developed endogenous technological change is lead by innovation (i.e. R&D), while if the country is developing technical change is lead by imitation activities and absorption capability, which is, paraphrasing Rogers (2004), the ability to access and fruitfully exploit new technological knowledge.

A synthetic representation of innovation-imitation dynamics is provided by the *technological gap* idea, originally formulated by Nelson and Phelps(1966).[1]

In this context, economies are distinguished into the *leader*, which is the country having the higher technological (or efficiency) level in a certain period, and all the others, called *followers*.

To model technological change in follower economies it is assumed that the level of efficiency depends on country and period characteristics as well as on technological gap, which proxies the technological and organizational transfer from the technology-leader country (Dorwick and Nguyen (1989); Verspagen (1991); Bernard and Jones(1996a); Bernard and Jones(1996b); Harrigan(1999); Dowrick and Rogers(2002); Griffith et al.(2004); Scarpetta

[1]In their seminal work, Nelson and Phelps use the technological gap idea to describe the technological dynamics of an industry. The extension of the framework to the study of cross-country technological interaction is due to Hansson and Herkson(1994).

and Tressel (2004), Bianchi and Menegatti (2005)). This implies that technological growth in the frontier economy accelerate technical change in laggard economies by widening their production possibility set. Thus, it is presumed that, for subsequent long run technological and output growth, the process of assimilating existing technologies in less developed countries is not unlike that of creating entirely new technologies in the developed ones (Pack and Westphal (1986)).

At this point, it is interesting to notice that cross-country conditional convergence prediction, that is, once structural differences have been equalised, poor economies' labour productivity levels will approach in the long run the ones of their richer counterparts, can originate from both neoclassical framework and from the theory of technological transfer. In particular, while the Solow (1957) model, assuming decreasing marginal productivity of capital, foretells that laggard countries in the short run will exhibit higher rates of output growth, due to their relative faster pace of capital accumulation; in endogenous growth literature, convergence tendencies arise because, although innovation tends to increase labour productivity and technological differences between countries, technological diffusion tends to decrease them (Fagerberg (1988)). Such a convergence process, originated by technological transfer is know in the literature as *technological catch-up*.[2]

Thus, two are the theoretical cross-country convergence driving forces: capital accumulation (i.e. neoclassical convergence inner driver) and technological transfer (i.e. endogenous or Schumpeterian engine of growth).

In the spirit of the seminal contribution of Dorwick and Rogers (2002), this paper attempts to reconcile neoclassical and technological catch-up traditions, looking at convergence determinants in manufacturing sectors.

The reason because I concentrate on industrial production, rather than on whole GDP, is that I believe that the main technological convergence effect might show up in this sector. In fact, as outlined by Lall (2001), manufacturing production has become increasingly world integrated and, then, technological transfer from developed to developing countries is likely to take place.

In particular, my original contribution focuses on manufacturing compartments. That

[2]See Rogers (2003) for an excellent review on technological catch-up literature.

different sectors might exhibit heterogeneous convergence tendencies rests on the premise that industrial production does have neither an homogeneous capital intensity nor an homogeneous technological content. So, convergence inner drivers and rate of convergence can be expected to differ at sectoral level.

To analyse this possibility, following Lall (2000) taxonomy, I divided industrial production into different categories according to their technological content. The categories used are: Resource Based (RB), in which the value of the production is essentially given by the possession of primary resources (e.g. processed food, manufactured tobacco, refined petroleum products, processed glass and metals); Low Technology (LT), which includes all the industries whose Research and Development (R&D) expenditure is below the 1% of sales' value (e.g. garments, footwear, pottery and cutlery); Medium Technology (MT), where R&D expenditure accounts for more than 1% and less of 4% of sales (e.g. automotive industry, perfumery, fertilizers, pesticides, textile and agricultural machinery); and High Technology (HT), where the R&D expenditure is greater than 4% of sale's value (e.g. electronics, medical instruments and aerospace).

The only works, among the ones I am aware of, that have attempted a similar analysis are the ones of Bernard and Jones (1996a) and Bernard and Jones (1996b). In particular, they provide a descriptive empirical analysis of classical and technological convergence, employing a neoclassical model augmented by a technological catch-up term and human capital, disaggregating GDP into primary, secondary and tertiary productive activities. According to their results, capital accumulation in the main convergence driving force, because labour productive tendency to converge among countries is greater that technological catch-up degree.

The present work differs from the recent applied literature on convergence inner drivers in two further respects.

Evaluating the relative strength of capital accumulation and technological transfer for cross country convergence represents a multitask objective. It requires, first, to properly model technological diffusion and, second , the reduced form employed for empirical analysis must allow to distinguish among the two potential convergence forces.

To accomplish the first requirement, I explicitly verify whether the representations of technological transfer process employed, all based on technological gap idea, are supported by data. In particular, I test whether technological gap and absorption capabilities, proxied by secondary and tertiary education, boost technology growth. As Griffith et al.(2004) and Scarpetta and Tressel (2004), my results support the hypothesis that technological growth rate is enhanced by technological transfer, in all manufacturing sectors and countries.

The second requisite is satisfied employing an original framework that combines neoclassical and endogenous growth theories of technological catch-up, in the spirit of Bianchi and Menegatti (2005). In fact, among the models I am aware of, the only ones that allow for testing simultaneously technological and classical conditional convergence, through the separation of capital deepening and technology diffusion terms, are the ones of Bianchi and Menegatti (2005) and Pigliaru (2003). My preference towards the first one is motivated by the fact the empirical implementation of Pigliaru (2003) framework seems to be very difficult, unless one is ready to assume that cross-country growth regressors in a panel data setting are strictly exogenous (in fact no empirical testing is provided).

My results, obtained employing the within group instrumental variable estimator, show that cross-country convergence determinants vary across sectors. In particular, I find that technological transfer constitutes the main driving force in Medium, High Technology and Resource Based sectors while both diminishing returns to capital and technological transfer play a role in Low Technology. Thus, it can be observed that technological diffusion is likely to lead long-run cross-country labour productivity equalisation in the most technologically dynamic sectors.

Moreover, the fastest speed of technological catch-up is found in HT. This supports the hypothesis that these industries are the ones opening the better prospects in terms of value added growth, especially from laggard economies perspective.

Finally, it is observed that tertiary education, better fulfilling the capabilities requirements needed to fruitfully exploit the existing technological gap, enhances technological transfer more than secondary education.

The paper is organised as follows. Section two presents formally how technological transfer among leader and followers has been modeled. In the third I derive the reduced form adopted for subsequent empirical analysis. In the fourth details on data sources and estimation technique employed are provided. In the fifth part, the results obtained on both technological growth determinants and convergence driving forces are discussed. Final remarks and policy implications conclude.

The appendix illustrates the superlative index number methodology employed to compute technological variables.

2 Technology growth determinants: a formal representation

In the multicountry setting considered here, where economies are separated into the leader (i.e. the country having the higher efficiency level) and the followers, the key issue for convergence tendencies is how rapidly the discoveries made in leading country diffuse to the others.

Assuming that value added in each economy is produced according to a standard neoclassical production technology,[3] the level of efficiency in follower country i at date t (i.e. A_{it}) is modeled as a first order autoregressive distributed lag [ADL(1,1)] process, such that efficiency level in i is cointegrated with the one of leader economy, L. Formally:

$$lnA_{it} = \alpha_1 lnA_{it-1} + \alpha_2 lnA_{Lt} + \alpha_3 lnA_{Lt-1} \tag{1}$$

Assuming long-run homogeneity (i.e. $\alpha_2+\alpha_3/(1-\alpha_1) = 1$) and considering an idiosyncratic error term, Equation (1) can be rewritten in its Error Correction Model form as:[4]

$$g_{it} \equiv \Delta lnA_{it} = \alpha_2 \Delta lnA_{Lt} + (1-\alpha_1) ln\left(\frac{A_{Lt-1}}{A_{it-1}}\right) + u_{it} \tag{2}$$

where $ln\left(A_{Lt-1}/A_{it-1}\right)$ is usually called *technological gap*. This term represents the distance from the technological frontier and captures the potential for technology transfer (Griffith et al.(2004), p.886).

Explicitly considering a constant country specific component of followers' technical progress,

[3]The neoclassical production function is characterised for being homogeneous of degree 1 and for exhibiting diminishing marginal returns to each cumulative factor of production.

[4]Equation (2) is obtained subtracting lnA_{it-1} from each side of (1) and adding and subtracting $\alpha_2(lnA_{Ljt-1})$ to the right hand side.

g_i, and a time specific term, g_t,[5] Dowrick and Rogers (2002) provide a panel data specification of technological catch-up process. This is done rewriting Equation (2) as follows:

$$g_{it} = g_i + g_t + \phi ln\left(\frac{A_{Lt-1}}{A_{it-1}}\right) + u_{it} \tag{3}$$

Thus, if follower countries are benefiting from technological transfer the coefficient ϕ will be positive. In particular, ϕ can be interpreted as the 'speed' of technology diffusion due to technological transfer *potential* (i.e. technological gap).

Finally, to take into explicit consideration that technogical gap can enhance technology growth when the recipient economy possess the appropriate capacities, technological gap is operatively interacted with absorption capabilities, represented by Ψ_{it}. Thus, Equation (3) can be rewritten as:

$$g_{it} = g_i + g_t + \eta\left[\Psi_{it} * (ln\left(\frac{A_{Lt-1}}{A_{it-1}}\right)\right] + u_{it} \tag{4}$$

where, coefficient η corresponds to the speed of diffusion due to *effective* technological transfer (i.e. technological gap *and* absorption capabilities).

It is worth noticing that different scholars have given different interpretations of technological reception process. For example, in the view of Nelson and Phelps (1966) and Barro and Sala-i-Martin (1995) absorption capabilities are proxied by human capital, while for Sachs and Warner (1997) they are mostly related to trade openness; finally Hansson and Henrekson (1994) consider both human capital and trade openness. As mentioned, in this paper I will concentrate on human capital.

To conclude, I briefly illustrate the empirical counterparts of technological variables of interest:

- the level of technical efficiency is approximated employing Total Factor Productivity (TFP) or Solow residual, calculated according the superlative index methodology of Caves(1982a) and Caves et al.(1982b),as:

$$TFP_{it} = ln\left(\frac{Y_{it}}{\overline{Y_t}}\right) - \tilde{\sigma}_{it} ln\left(\frac{L_{it}}{\overline{L_t}}\right) - (1-\tilde{\sigma}_{it})ln\left(\frac{K_{it}}{\overline{K_t}}\right)$$

[5] Note that leader's technological change, being the same for all followers, can be interpreted as a component of the time specific term.

Further details on this method can be found in the Appendix;

- technological gap is computed subtracting TFP of country i from leader economy's TFP:

$$TFPgap_{it} = TFP_{Lt} - TFP_{it}$$

- TFP growth in country i is represented by the difference of two TFP index calculated at different points of time:

$$g_{it} = TFP_{it} - TFP_{it-1}$$

3 Classical *vs* technological convergence: the model

The framework I use to test the relative strength of capital accumulation and technological transfer as convergence driving forces combines the neoclassical and endogenous representations of economic growth process. This is done relaxing the hypothesis of a common technology growth rate among countries from the textbook Solow model. In particular, the technological catch-up hypothesis is adopted. Thus, variations in countries' output growth rates are explained by relative distance from steady state together with *both* decreasing returns to capital *and* international technology transfer. Hence, it is possible to test both neoclassical and endogenous growth mechanism of convergence. A similar specification is provided by Bianchi and Menegatti(2005).

To begin, I briefly recap the basic hypothesis and results of the neoclassical model in a multicountry setting, without explicitly considering sectoral differences, for notational convenience.

In the neoclassical model, a Cobb-Douglas production function with constant returns to scale is assumed:

$$Y_{it} = A_t K_{it}^{\alpha} L_{it}^{1-\alpha} \tag{5}$$

where Y_{it}, K_{it} and A_t stand respectively for output, capital stock and labour augmenting technology in country i, at time t. Note that K_{it} can be constituted by both physical and human capital, as in Mankiw, Romer and Weil (1992). Here, for simplicity, I take only physical capital stock into consideration.

Proceeding with the set-up of Solow model, capital stock is accumulated at fixed rate, s_i, and depreciates at rate δ while labour input L_{it} grows at the constant rate n:

$$\dot{K_{it}} = s_i Y_{it} - \delta K_{it}$$

$$L_{it} = L_0 e^{nt}$$

In the neoclassical model, a country and time invariant technology growth rate, equal to g, is assumed:

$$A_t = A_0 e^{gt}$$

Differently, I am going to assume that technical growth rate is country and time specific:

$$A_{it} = A_0 e^{g_{it} t} \tag{6}$$

where g_{it} is specified as in Equation (3).

A well know result of the neoclassical model is that the growth rate of output in unit of effective labour (i.e. $\hat{y} = Y/AL$) is proportional to countries' distance from steady state (i.e.$\hat{y}^*$). In formal terms:

$$\gamma_{\hat{y}} = -b \left[ln \left(\frac{\hat{y}}{\hat{y}^*} \right) \right] \tag{7}$$

where $\gamma_{\hat{y}}$ indicates output growth rate and $b = (1-\alpha)(g+n+\delta)$. Parameter b indicates how rapidly economy's output per effective worker approaches its steady state value.

Solving the differential equation in Equation (7) and subtracting $ln\hat{y}_{i0}$ from both side, the following estimable equation is obtained, after having explicitly expressed steady state output level:

$$ln\hat{y}_{it} - ln\hat{y}_{i0} = -\beta ln\hat{y}_{i0} + \beta \left(\frac{\alpha}{1-\alpha} \right) [ln(s) - ln(g+n+\delta)] + \epsilon_{it} \tag{8}$$

where $\beta = (1 - e^{-bt})$. Whether the conditional convergence hypothesis is rejected or not depends on the coefficient on initial output level, β: if negative, conditional convergence prediction can not be rejected. Starting from these results, I turn to derive the reduced form of my model.

To begin, I group steady state proxies into variable X_{it} and I indicate $\beta * (\alpha/1-\alpha)$ as γ, such that:

$$ln\hat{y}_{it} - ln\hat{y}_{i0} = -\beta ln\hat{y}_{i0} + \gamma X_{it} + \epsilon_{it} \tag{9}$$

Since Equation (9) is expressed in unobservable units of effective labour, it can be rewritten in per capita terms (i.e. y=Y/L) and it can be solved for a discrete time period. These transformations are particularly useful for empirical work. In formal terms, value added growth rate in country i over the period $(0,t)$ can be approximated as:

$$\left(\frac{lny_{it} - lny_{i0}}{t}\right) - \left(\frac{lnA_{it} - lnA_0}{t}\right) = -\frac{\beta}{t}lny_{i0} + \frac{\beta}{t}lnA_0 + \frac{\gamma}{t}X_{it} + \epsilon_{it} \tag{10}$$

Now, using Equation (6), I obtain:

$$\left(\frac{lny_{it} - lny_{i0}}{t}\right) = g_{it} + \frac{\beta}{t}lnA_0 - \frac{\beta}{t}lny_{i0} + \frac{\gamma}{t}X_{it} + \epsilon_{it} \tag{11}$$

Then, Equation (5) is employed for rewriting initial per capita value added:

$$\left(\frac{lny_{it} - lny_{i0}}{t}\right) = g_{it} + \frac{\beta}{t}lnA_0 - \frac{\beta}{t}\left[lnA_0 + \alpha lnk_{i0}\right] + \frac{\gamma}{t}X_{it} + \epsilon_{it} \tag{12}$$

Finally, noting that the terms in initial technological levels cancel out and substituting Equation (3) into (12):

$$\left(\frac{lny_{it} - lny_{i0}}{t}\right) = g_i + g_t + \phi ln\left(\frac{A^L_{t-1}}{A_{i,t-1}}\right) - \frac{\widetilde{\beta}}{t}lnk_{i0} + \frac{\gamma}{t}X_{it} + \epsilon_{it} \tag{13}$$

where $\widetilde{\beta}$ is β multiplied by α.

Finally, explicitly considering physical and human capital accumulation rates, s_K and s_H, as steady state proxies, and grouping all time invariant terms but country specific terms into ξ_i and all country invariant but time varying terms into ξ_t,I obtain the reduced form of my model:

$$\left(\frac{lny_{it} - lny_{i0}}{t}\right) = \xi_i + \xi_t + \phi ln\left(\frac{A^L_{t-1}}{A_{i,t-1}}\right) - \frac{\widetilde{\beta}}{t} lnk_{i0} + \frac{\gamma_1}{t} lns_{Kit} + \frac{\gamma_2}{t} lns_{Hit} + \epsilon_{it} \quad (14)$$

As in Bianchi and Menegatti (2005), the separation of initial country specific capital stock and technological level (i.e. TFPgap) allows to test for both classical and technological conditional convergence simultaneously.

In particular, neoclassical conditional convergence is found when the coefficient multiplying initial capital is negative. That is, due to capital diminishing marginal productivity, countries relatively close to steady-state will experience a slowdown in growth.

Concerning technological conditional convergence, this hypothesis is not rejected if coefficient ϕ, which represents the speed of technological catch-up due to technological transfer potential, is positive.

By the same tokens, if Equation (4) instead of Equation (3) is used , the following estimable is found:

$$\left(\frac{lny_{it} - lny_{i0}}{t}\right) = \xi_i + \xi_t + \eta \left[\Psi_{it} ln\left(\frac{A^L_{t-1}}{A_{i,t-1}}\right)\right] - \frac{\widetilde{\beta}}{t} lnk_{i0} + \frac{\gamma_1}{t} lns_{Kit} + \frac{\gamma_2}{t} lns_{Hit} + \epsilon_{it} \quad (15)$$

Also in this case neoclassical conditional convergence hypothesis is not rejected when the coefficient multiplying initial capital is negative and for technological conditional convergence the parameter η, which stands for technological catch-up speed due to effective technological transfer, must be positive.

4 Data and estimation technique

The dataset I use comprises the following variables observed at annual intervals from 1980 to 1995, for 28 developed and developing countries[6]:

- Labour productivity;
- Steady state proxies: physical and human capital accumulation rates;

[6]See Table 1 for sample details

- Absorption capabilities proxies: secondary and tertiary schooling attainment rate;
- Total Factor Productivity (TPF) Growth, TFP levels and TFP Gap.

All these variables but the schooling ones are disaggregated by technological sector, according to Lall (2000) taxonomy.

Labour productivity, in each country and sector, is measured as manufacturing value added per worker and it is denominated in 1996 international dollars. Data are expressed in 1996 international dollars to allow international and intertemporal comparisons. They are obtained combining UNIDO Industrial Statistics Database 2004, at 3-digits of ISIC Code (Revision 2), World Bank Development Indicators and the latest version of Penn World Tables. In particular, from UNIDO I collected disaggregated data on workers and on manufacturing value added in Local Currency Unit (LCU); from World Bank Development Indicators (WDI), GDP data in LCU; finally, from Penn World Tables (PWT 6.1), GDP data expressed in Purchasing Power Parity. After having calculated sectoral value added in manufacturing as percentages of GDP, using World Bank and UNIDO data in LCU, I combined such percentages figures with WDI and PWT6.1. My preferred measure of real value added in manufacturing is based on Penn World Tables Real GDP Chain Index (RGDPCH). This is because RGDPCH does not suffer from the so-called 'Laspeyres fixed-based problem' and, then, it is the most appropriate measure when intertemporal comparisons are at issue.[7]

Initial capital stock data come from originally estimated sectoral capital stock series.[8]

Physical capital accumulation rates are calculated as Gross Fixed Capital Formation share to manufacturing value added. Both series are taken from UNIDO database.

To proxy human capital accumulation rate in each country, I use the average years of schooling in the population over age 15. This series comes from Barro and Lee(2000) dataset, which reports schooling variables only at five years interval. To overcome this difficulty, I interpolate the available data implicitly assuming that the between-observed values lie on a straight line.[9]

[7] Summers and Heston (1991).

[8] See for further details *Improving PIM to measure capital stock. Any implication for growth?* comprised in the present thesis.

[9] My preference towards population over age 15, instead of 25, which is also available in Barro and Lee dataset, is motivated by the fact that working age in developing countries can be quite low. See for further

Absorption capabilities are proxied by human capital indicators as in the tradition of Nelson and Phelps (1966), Baumol (1986), Sala-i-Martin (1995) and Rogers (2004). In particular, I choose secondary and tertiary schooling attainment rate. Both series are taken from Barro and Lee(2000) dataset.

All technological variables are estimated employing the superlative index number approach introduced by Caves(1982a) and Caves et al.(1982b) , using the previously mentioned data sources. Further details on this methodology can be found in the Appendix, while their empirical counterparts have been presented in Section 2.

Turning to the estimation technique, I employ the within group estimator to test for both technology growth determinants and conditional convergence inner drivers .

In both cases, I begin my empirical analysis undertaking a battery of Hausmann test. This is done to evaluate whether country' unobserved heterogeneity has to be modelled as fixed effect or random effect.

Having rejected random effect hypothesis in all sectors and countries, in both TFP growth determinants and conditional convergence analysis, the within group estimator can be thought as the best choice, in terms of consistency and efficiency.

In the case of TFP growth determinants, all results reported are consistent with the hypothesis of non-spherical error terms.

In the analysis of classical and technological conditional convergence, I explicitly take into account the possibility of endogenous regressors using Instrumental Variables. In particular, all regressors were instrumented with the value of their first lag.

To take time heterogeneity, ξ_t, into account I included a set of relevant time dummies as done by Islam (1995) and Griffith et al. (2004).

5 Results

5.1 TFP growth determinants

In this section I examine the role played by technological gap and absorption capabilities in determining technology growth rates. The analysis are carried by sector, according

details Bennell(1996).

to Lall's technological taxonomy, and by country, separating developed economies from developing ones. The latter distinction is important because it allows to check whether technological transfer process is taking place in both type of countries.

To begin, I analyse descriptively technological variables data. I identify which countries have higher and lower TFP indexes, reporting the highest two (i.e. the leader and the most productive country among the followers) and the lowest one. Moreover, to have an idea of TFPgap distribution along time, I provide informations on the mean and standard deviation of the exponent of the negative of the TFPgap, $exp(-TFPgap)$. This measure corresponds to each country's TFP as a proportion of leader's TFP. It has the great advantage of being positive and, then, easy to interpret: the closer to 1, the smaller the TFPgap and, then, the closer to leader's technical level.

From Table 2, it can be observed that USA is the leader country in all sectors and that Japan represents its immediate follower, although with some few exceptions. Regarding laggard countries, India and Bangladesh, the only least developed countries in my sample, have the sad record of least efficient economies.

Turning to TFPgap distribution features, it could be noticed that in Low, Medium and High Technology sectors the mean of TFPgap measure is greater in 1995 than it was in 1980; then, on average, countries did get closer to the leader. In Resource Based and Manufacturing as a whole, on the other hand, such a measure seems stagnating or slightly decreasing, although it must be remarked that Resource Based is the sector exhibiting the lowest technical gap in the whole period. These results are consistent with the ones that Griffith et al. (2004) and Scarpetta and Tressel (2004) obtain for OECD countries.

Finally, the standard deviation of TFPgap is decreasing in all sectors but Low Tech where it is constant. This means that, in the period considered, countries not only did get closer to the leader but also to each other. The same is found by Griffith et al. (2004).

Table 3 reports the results of technological growth determinants (i.e. Equations (3) and (4)). It can be seen that different measures of human capital are considered in constructing the interaction terms, in particular the following specifications of technological transfer process are adopted:

1. $\Delta TFP_{it} = \phi(TFPgap_{t-1}) + u_{it}$

2. $\Delta TFP_{it} = \eta_1(AverageYearsofSchooling_{t-1} * TFPgap_{t-1}) + u_{it}$

3. $\Delta TFP_{it} = \eta_2(\%Pop.Sec.Sc._{t-1} * TFPgap_{t-1}) + u_{it}$

4. $\Delta TFP_{it} = \eta_3(\%Pop.Tert.Sc._{t-1} * TFPgap_{t-1}) + u_{it}$

As Griffith et al. (2004) and Scarpetta and Tressel (2004), my results support the hypothesis that technological growth rate is enhanced by technological transfer. In fact, a significative positive correlation is found between ΔTFP_{it} and $TFPgap$ considered alone or interacted with human capital measures.

Then, distinguishing among countries, it can be noticed that the impact of technological gap is greater for developing than developed countries, in all sectors but Medium and High Tech. This finding can be motivated recalling what Baumol(1986) defines *product mix* and that is usually indicated as *appropriate technological gap* in technological catch-up literature (Rogers (2003)).[10] The idea is that not all available technical knowledge benefit laggard economies. In other words, some countries can be so far behind the technological frontier that, although having a great technological transfer potential (i.e. large technological gap), they can effectively absorb very little technology. Thus, it seems that the technological gap in MT and HT is not appropriate for developing countries, in the sense that it can not benefit laggard economies' technological growth in the short run.

Then, turning to absorption capabilities, it can be seen from specification 2 that an extra year of schooling is worth more in developing countries than in developed ones (i.e. specification 2).

Moreover, it seems that the impact for technological catch-up of both secondary and tertiary education is greater for developing than developed countries, in all sectors but High Technology (i.e. specifications 3 and 4). This latter finding reinforces the claim that frontier technological knowledge in this sector can not be easily transferred to developing countries, because not 'appropriate'.

Finally, it is worth noticing that secondary education is the most relevant schooling grade

[10]

> (...) [a] less developed country that produces no cars can not benefit from the invention and adoption of a better car-producing robot in Japan.

Baumol (1986), p.1080.
On this point, see also David (1993) [p.240].

for developing countries. Then, it could be said that secondary schooling properly complements the relevant technological gap in laggard economies, thus favoring technological growth. The same is true for tertiary education in developed countries. These results are in line with the ones of Gemmell (1996).

5.2 Classical and technological convergence

In what follows I evaluate the relative strength of capital accumulation and technological transfer as conditional convergence inner drivers. The analysis are made at sectoral level without distinguishing between developed and developing countries. This is because the focus here is on convergence tendencies between leader and followers and not on clustering dynamics. [11]

The specifications of yearly value added growth adopted are the following:

1. $\Delta lny_{it} = \beta lnk_{it-1} + \phi(TFPgap_{t-1}) + \gamma_1\ lns_{Kit} + \gamma_2 lns_{Hit} + \epsilon_{it}$
2. $\Delta lny_{it} = \beta lnk_{it-1} + \eta_1(\%Pop.Sec.Sc._{t-1} * TFPgap_{t-1}) + \gamma_1\ lns_{Kit} + \gamma_2 lns_{Hit} + \epsilon_{it}$
3. $\Delta lny_{it} = \beta lnk_{it-1} + \eta_2(\%Pop.Ter.Sc._{t-1} * TFPgap_{t-1}) + \gamma_1\ lns_{Kit} + \gamma_2 lns_{Hit} + \epsilon_{it}$

Table 4 reports estimation outcomes obtained for the three specifications.

In general terms, it could be noticed that conditional convergence hypothesis is supported in all sectors. This means that developing countries are catching up with their richer counterparts, in terms of labour productivity. Moreover, it is found that physical and human capital accumulation rates are positively related with value added growth, although they are not always significant predictors.[12] Similar results are found by Dowrick and Rogers (2002).

More in detail, Table 4 shows that the nature and the speed of convergence vary across sectors and technological transfer specifications.

Regarding the nature of convergence process, and then its inner drivers, it could be seen

[11] See for details the excellent review on empirical growth analysis of Durlauf, Johnson and Temple (2005).

[12] See for further details on growth predictors' robustness the 2 and 4 millions of regressions run in by Sala-i-Martin (1997a) and Sala-i-Martin (1997b).

that, Low Technology sectors exhibit both classical (i.e. negative and significant coefficient on initial capital stock) and technological convergence (i.e. positive and significant coefficient on TFPgap and interaction terms), with the only exception of specification (3); Medium and High Technology together with Resource Based show exclusively technological conditional convergence; and, finally, Manufacturing as whole, being literally the sum of the various compartments, presents, as expected, mixed evidence.

This kind of evidence partially agrees with Dowrick and Rogers (2002), who find that both capital accumulation and technological diffusion are determinant for long run cross-country equalisation of GDP per worker, while it disagrees with Bianchi and Menegatti (2005) and Bernard and Jones (1996a) and Bernard and Jones (1996b), who, employing extremely different datasets from mine, support only classical conditional convergence.

The result of cross-country classical and technological conditional convergence in LT can be motivated taking into account the intrinsic characteristics of these industries. In particular, these sectors are traditionally labour intensive and the techniques involved are relatively simple and almost mature. Then, on one hand, it can be claimed that capital stock exhibits diminishing marginal returns, thus supporting classical convergence prediction; and, on the other, technological convergence seems also likely because the highly standardised production processes might be imitated quite easily by developing countries.

In the case of MT and HT the finding that technological transfer, and not capital accumulation, is the convergence inner driver can be explained considering the high technological dynamism these sectors exhibit, in both developed and developing countries. In fact, it is true that knowledge intense sectors channel the greatest amount of R&D efforts in advanced economies and that, in the last thirty years, an unprecedented process of technology transfer from North to South has taken place in these industries (UNIDO (2002); UNCTAD (2002)). Through the means of Foreign Direct Investments (FDI), licensing, exports of capital goods, migration of skill workers, world top Multinational Corporations, which happen to be in the High Tech business, have started to diffuse technologies developed at home, both to re-locate their production or to enter new factor and final good markets (UNCTAD (2005)).

Regarding RB, technological conditional convergence evidence can be interpreted taking into account both the great importance of such industries for developing countries' exports and the massive process of mechanisation such compartments have experienced in the recent years. For example, as noticed by Lall (2000), modern food and metal processing, requires the use of very advanced techniques, especially when international standards have to be met. Thus, it might be claimed that, laggard economies, traditionally competing in world market through RB productions, could benefit from technological transfer enhanced by international trade, according to the theoretical point of view of Sachs and Warner (1997). Moreover, the increasingly mechanised nature of production could have entailed frontier technological knowledge to be as important as in knowledge intense sectors, providing the necessary incentives to imitation.

At sectoral level, my analysis confirms the hypothesis of non-homogeneous speed of technological convergence.

In particular, the fastest speed of technological catch-up is found in HT and the lowest in LT sectors. Such differences can be explained considering that the returns of productive activities have proved to be higher in knowledge intense than in traditional sectors. In particular, Lall (1997) notices that in HT even labour intensive activities, such as assembly, are more stable, skill-creating and externality generating than in LT. Thus, technological catch-up appears faster in HT because these industries are the ones opening the better prospects in terms of value added growth.

To conclude, I discuss the results provided by alternative specifications of technological transfer.

Comparing Table 4 columns, it can be easily seen that the elasticity of output growth with respect to technological gap terms increases its value when interacted with human capital proxies. In particular, in specification (1) output growth elasticity with respect to technological transfer (i.e. coefficient ϕ) is between 0.13 and 0.5 (i.e. to a point percentage change in TFPgap value added growth increases between 0.2% and 0.5%), in specification (2) it increases almost to 2 and finally it is comprised between 1.1 and 7.8 in specification (3), where technological transfer is due not only to technological gap but also to tertiary schooling.

The general comment that could be done is that the higher the school grade the better

the potential for technological transfer is complemented, so the faster the technological convergence rate or speed.
Moreover, it is interesting to note that these results confirm the previous analysis on technology growth determinants, for all sectors and specifications, exception made for MT and HT in specification (3) (See first column of Table 3). In particular, in knowledge intense sectors, technological convergence speed seems the highest when TFPgap is interacted with tertiary education and not with secondary education, as it could be expected looking at Table 3.
On one hand, this finding might signal that the skills obtained in secondary schooling are not sufficient to imitate and effectively use frontier HT knowledge. On the other, it could be claimed that tertiary education, which is highly subsidised in low income countries (Glewwe and Kremer (2005)), is particularly valuable not only to progress in technical knowledge (Foster and Rosenzweig (1995)) but it brings also side effects, such as positive externalities, production linkages and general equilibrium effects ((Schultz (2002); Strauss and Thomas (1995)), which are crucial for output growth especially in developing countries.

6 Conclusions

This paper provides new empirical evidence on cross-country classical and technological conditional convergence in manufacturing sectors, identified according to Lall (2000) technological taxonomy.
Instrumentally to main analysis, I verify that the representations of technological transfer employed are supported by data. Similarly to Griffith et al. (2004) and Scarpetta and Tressel (2004), my results confirm the hypothesis that technological growth rate is enhanced by technological transfer, in all manufacturing sectors and countries.
Turning to classical and technological convergence predictions, my results highlight that cross-country convergence determinants vary across sectors. In particular, I find that technological transfer constitutes the main driving force in Medium, High Technology and Resource Based sectors while both diminishing returns to capital and technological transfer play a role in Low Technology. Thus, it can be observed that technological diffu-

sion is likely to lead long-run cross-country labour productivity equalisation in the most technologically dynamic sectors, where in the present multicountry setting technological dynamism is represented by both innovation and imitation activities.[13]

Moreover, the fastest speed of technological catch-up is found in HT. This supports the hypothesis that these industries are the ones opening the better prospects in terms of value added growth, especially from laggard economies perspective.

The findings illustrated so far seem to confirm that, in technological dynamic sectors, technical progress (e.g. knowledge diffusion) counteracts the effects of decreasing marginal productivity, boosting long run output growth, as predicted by the seminal contribution of Romer (1986).

Finally, it is observed that tertiary education, better fulfilling the capabilities requirements needed to fruitfully exploit the existing technological gap, enhances technological transfer more than secondary education.

From a policy perspective, this evidence shows that laggard economies can improve their relative position. To catch-up with their richer counterparts, developing countries should enter R&D intense industries and target their industrial policy towards the development of dynamic advantages, such as knowledge and skills, rather than relying only on large production capacity, cheap labour and abundant natural resources. In particular, as Lall (2004) suggests, laggard economies have to find an access to foreign technology, via formal imports in both internalised and externalised forms (e.g. FDI and licesing, respectively). Moreover, they have to build domestic absorption capabilities, such as advanced technical skills acquired through tertiary education, and so, they have to provide institutional infrastructure for learning.

To conclude, I want to mention that an interesting further line of research could be investigating whether the results obtained are robust to different specifications of the technological catch-up process. In particular, the hypothesis used here was that technological improvements over time were a linear function of the technological gap.

What will the results be if technological change would allowed to be a non-linear function

[13]Remember that Resource Based productions are largely world integrated and have complex scale and technical requirements, like Medium and High Technology sectors.

of the technological gap? Will be ‘falling behind’ episodes and clustering tendencies likely to happen?

The empirical test of cross-country convergence inner drivers through non parametric techniques constitutes an exciting research challenge.

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Developed OECD	**Developed NON OECD**	**Developing Middle Income**	**Developing Low Income**
Australia	Cyprus	Bolivia	Bangladesh
Austria	Hong-Kong	Chile	India
Finland	Israel	Egypt	
Greece	Singapore	Indonesia	
Italy		Iran	
Japan		Jordan	
Korea		Malaysia	
Norway		Philippines	
Spain		Sri Lanka	
United Kingdom		Turkey	
United States		Venezuela	

Table 1: Country Sample

Technological Sector	TFP	1980	1985	1990	1995
Resource Based					
	First TFP	USA	USA	USA	USA
	Second TFP	UK	UK	Australia	Australia
	Lowest TFP	India	India	India	India
	Mean exp(-TFPgap)	0.44	0.45	0.46	0.44
	SD exp(-TFPgap)	0.22	0.22	0.23	0.2
Low Tech.					
	First TFP	USA	USA	USA	USA
	Second TFP	Japan	UK	Japan	Australia
	Lowest TFP	Bangladesh	Bangladesh	Bangladesh	Bangladesh
	Mean exp(-TFPgap)	0.39	0.41	0.40	0.40
	SD exp(-TFPgap)	0.26	0.27	0.26	0.26
Medium Tech.					
	First TFP	USA	USA	USA	USA
	Second TFP	Japan	Japan	Japan	Japan
	Lowest TFP	India	India	Bolivia	Bolivia
	Mean exp(-TFPgap)	0.38	0.37	0.35	0.39
	SD exp(-TFPgap)	0.25	0.26	0.23	0.22
High Tech.					
	First TFP	USA	USA	USA	USA
	Second TFP	Japan	UK	Japan	Finland
	Lowest TFP	Bangladesh	Bangladesh	Bangladesh	Bangladesh
	Mean exp(-TFPgap)	0.38	0.37	0.35	0.39
	SD exp(-TFPgap)	0.24	0.24	0.22	0.22
Manufacturing					
	First TFP	USA	USA	USA	USA
	Second TFP	Japan	Japan	Japan	Australia
	Lowest TFP	India	Bangladesh	Bangladesh	Bangladesh
	Mean exp(-TFPgap)	0.4	0.4	0.41	0.39
	SD exp(-TFPgap)	0.23	0.24	0.23	0.22

Table 2: TFP descriptive statistics

Dependant variable: ΔTFP_{it}	**All Countries**	**Developed**	**Developing**
Resource Based			
(1) $TFPgap_{t-1}$	.34 (.05)	.28 (.05)	.35 (.05)
(2) $TFPgap_{t-1} * Av.Sc.$	.05 (.008)	.033 (.008)	.08 (.01)
(3) $TFPgap_{t-1} * Sec.Sc.$	.77 (.19)	.34 (.13)	3.3 (.8)
(4) $TFPgap_{t-1} * Tert.Sc.$	.92 (.22)	.61 (.23)	1.04 (.3)
Low Technology			
(1) $TFPgap_{t-1}$	.3 (.062)	.26 (.07)	.3 (.07)
(2) $TFPgap_{t-1} * Av.Sc.$	.04 (.008)	.02 (.007)	.05 (.012)
(3) $TFPgap_{t-1} * Sec.Sc.$	.97 (.22)	.38 (.15)	2.67 (.71)
(4) $TFPgap_{t-1} * Tert.Sc.$	.86 (.23)	.65 (.25)	.89 (.27)
Medium Technology			
(1) $TFPgap_{t-1}$	.28 (.04)	.3 (.06)	.28 (.05)
(2) $TFPgap_{t-1} * Av.Sc.$	.047 (.005)	.035 (.007)	.054 (.009)
(3) $TFPgap_{t-1} * Sec.Sc.$	.86 (.18)	.42 (.15)	3.57 (.65)
(4) $TFPgap_{t-1} * Tert.Sc.$	.74 (.18)	.69 (.18)	.76 (.22)
High Technology			
(1) $TFPgap_{t-1}$	.27 (.05)	.33 (.08)	.25 (.06)
(2) $TFPgap_{t-1} * Av.Sc.$	.047 (.007)	.037 (.008)	.052 (.009)
(3) $TFPgap_{t-1} * Sec.Sc.$	1.1 (.16)	.56 (.16)	2.5 (.60)
(4) $TFPgap_{t-1} * Tert.Sc.$	.79 (.22)	.9 (.32)	.77 (.26)
Manufacturing			
(1) $TFPgap_{t-1}$	.28 (.06)	.27 (.08)	.28 (.07)
(2) $TFPgap_{t-1} * Av.Sc.$	.042 (.007)	.03 (.008)	.054 (.012)
(3) $TFPgap_{t-1} * Sec.Sc.$	.61 (.15)	.32 (.12)	2.1 (.66)
(4) $TFPgap_{t-1} * Tert.Sc.$	.63 (.19)	.59 (.2)	.64 (.24)

Table 3: Impact of Technological Transfer on TFP growth. Robust Std. Errors in Parenthesis

Dependant variable: Δlny_{it}	**Specification (1)**	**Specification (2)**	**Specification (3)**
Resource Based			
lnk_{it-1}	-.04 (.06)	-.08 (.06)	-.07 (.07)
$TFPgap_{t-1}$	.29*** (.08)	–	–
$TFPgap_{t-1} * Sec.Sc.$	–	.68** (.32)	–
$TFPgap_{t-1} * Tert.Sc.$	–	–	2.39* (1.3)
lns_{Kit}	.13*** (.04)	.16*** (.04)	.18***(.05)
lns_{Hit}	.32*** (.12)	.1 (.15)	.14 (.16)
$cons$	-.1 (.71)	.1 (.71)	.9(.71)
F test that all $u_i = 0$; P.value:	.1	.1	.1
Low Technology			
lnk_{it-1}	-.09* (.06)	-.11** (.06)	-.1* (.06)
$TFPgap_{t-1}$	.13** (.05)	–	–
$TFPgap_{t-1} * Sec.Sc.$	–	.5* (.3)	–
$TFPgap_{t-1} * Tert.Sc.$	–	–	1.16 (1)
lns_{Kit}	.02 (.035)	.025 (.03)	.03(.04)
lns_{Hit}	.22** (.11)	.1 (.1)	.1(.16)
$cons$	.46 (.6)	.1* (.6)	1*(.6)
F test that all $u_i = 0$; P.value:	.7	.9	.95
Medium Technology			
lnk_{it-1}	-.02 (.05)	-.06 (.05)	-.08* (.05)
$TFPgap_{t-1}$	.25*** (.06)	–	–
$TFPgap_{t-1} * Sec.Sc.$	–	.5* (.3)	–
$TFPgap_{t-1} * Tert.Sc.$	–	–	1.9* (1.08)
lns_{Kit}	.017 (.04)	.023 (.045)	.009(.04)
lns_{Hit}	.32*** (.12)	.12 (.14)	.14(.14)
$cons$	-.63 (.56)	.41 (.6)	.6(.6)
F test that all $u_i = 0$; P.value:	.7	.88	.77
High Technology			
lnk_{it-1}	.16*** (.05)	-.01 (.05)	.012 (.05)
$TFPgap_{t-1}$	.5*** (.06)	–	–
$TFPgap_{t-1} * Sec.Sc.$	–	1.9*** (.3)	–
$TFPgap_{t-1} * Tert.Sc.$	–	–	7.8*** (1.3)
lns_{Kit}	.05 (.05)	.017(.05)	.02(.05)
lns_{Hit}	.12 (.16)	.35* (.19)	.45**(.2)
$cons$	-2.7*** (.6)	.55 (.6)	.6(.6)
F test that all $u_i = 0$; P.value:	.61	.72	.43
Manufacturing			
lnk_{it-1}	-.05(.05)	-.08* (.04)	-.08*(.04)
$TFPgap_{t-1}$	.17*** (.05)	–	–
$TFPgap_{t-1} * Sec.Sc.$	–	.42* (.26)	–
$TFPgap_{t-1} * Tert.Sc.$	–	–	.75 (.9)
lns_{Kit}	.1*** (.03)	.11***(.04)	.11***(.04)
lns_{Hit}	.2**(.08)	.06(.1)	.12(.11)
$cons$	.19 (.6)	.9* (.6)	.8(.5)
F test that all $u_i = 0$; P.value:	.5	.83	.94

Table 4: Whole sample. *** 1%; ** 5%; * 10% significance level.

Appendix

Total Factor Productivity (TFP) or Solow residual is the part of output growth not accounted for market transactions. It originates from growth accounting exercise and it is conventionally employed to measure technological progress. Following Diewert (1976), Caves et al. (1982b) derives an index number that allows TFP comparisons among countries. This index is *superlative*, meaning that is exact for the flexible aggregator function chosen (i.e. translog production function); and *transitive*, so that the choice of base country and year is inconsequential.[14]

Formally, I assume that value added of a generic country i is a function of capital stock and employment; that is translog with identical second-order term; that constant returns to scale apply and that inputs are measured perfectly and in the same units for each observation. In symbols:

$$\ln y_i = \alpha_{0i} + \alpha_{1i} lnl_i + \alpha_{2i} lnk_i + \alpha_3 (lnl_i)^2 + \alpha_4 (lnk_i)^2 + \alpha_5 (lnl_i * lnk_i)$$

Where constant returns to scale hypothesis requires $\alpha_{1i} + \alpha_{2i} = 1$ and $2\alpha_3 + \alpha_5 = 2\alpha_4 + \alpha_5 = 0$.

I review Caves et al.(1982) contribution, beginning with TFP index number for bilateral comparisons.

There are two countries, b and c; country b is the basis of comparison and the distance function $D_c(y_b, l_b, k_b)$ represents the minimum proportional decrease in y_b such that the resulting output is producible with the inputs and productivity levels of c. Or, $D_c(y_b, l_b, k_b)$ is the smallest input bundle capable of producing y_b using the technology in country a. In symbols:

$$D_c(y_b, x_b) = \min \{\delta \in \Re_+ : f_c(\delta x_b) \geq y_b\}$$

[14] *Exact* literally means that the resulting index is not an approximation. For details see Diewert (1976) and its result on the use of Tornqvist-Theil approximation to the Divisia index. *Flexible* is an aggregator function that can provide a second order approximation to an arbitrary twice differentiable linearly homogeneous function.

where $x_b = (k_b, l_b)$.[15] Assuming that producers are cost-minimisers and price takers in input markets, it can be shown that the Malmquist index (i.e. the geometric mean) of two distance functions for any two countries c and b gives the following TFP index:

$$TFP_{cb} = \frac{y_c}{y_b} \left(\frac{\bar{l}}{l_c} \right)^{\sigma_c} \left(\frac{\bar{k}}{k_c} \right)^{1-\sigma_c} \left(\frac{l_b}{\bar{l}} \right)^{\sigma_b} \left(\frac{k_b}{\bar{k}} \right)^{1-\sigma_b}$$

where a bar denotes an average over countries and $\sigma_i = (\alpha_i + \overline{\alpha})/\,2$, where (α_i) stands for labour's share in total costs for country i.

Similar reasoning can be applied to derive the multilateral version of TFP index, that allows for TFP comparisons among more than two countries. Taking sectoral heterogeneity explicitly into account, TFP level in country i, sector j at time t is:

$$TFP_{ijt} = \frac{Y_{ijt}}{\overline{Y_{jt}}} \left(\frac{\overline{L_{jt}}}{L_{ijt}} \right)^{\tilde{\sigma}_{ijt}} \left(\frac{\overline{K_{jt}}}{K_{ijt}} \right)^{1\tilde{-}\sigma_{ijt}}$$

where a bar denotes the geometric average over all countries for a given sector j and a year t and $\tilde{\sigma}_{ijt} = (\alpha_{ijt} + \overline{\alpha_j})/2$, where α_{ijt} is labour share in country i and industry$j$ and $\overline{\alpha_j}$ is the cross-country average for industry j.

Then, taking natural logarithms, the previuos expression becomes:

$$TFP_{ijt} = ln \left(\frac{Y_{ijt}}{\overline{Y_{jt}}} \right) - \tilde{\sigma}_{ijt} ln \left(\frac{L_{ijt}}{\overline{L_{it}}} \right) - (1 - \tilde{\sigma}_{ijt}) ln \left(\frac{K_{ijt}}{\overline{K_{jt}}} \right)$$

As originally noticed by Harrigan (1997), the variability in *actual* labour shares over value added makes difficult the empirical implementation of Equation (3). To solve this problem *smoothed* and not *actual* labour shares are usually employed.

Smoothed labour shares are simply obtained running a regression of actual labour shares on a constant and the capital to labour ratio:[16]

$$\alpha_{ijt} = \xi_i + \xi_j + \chi_{ij} ln \left(K_{ijt}/L_{ijt} \right)$$

[15] This notation implies that only one homogeneous output is produced using only one homogeneous input. For further details on productivity measurement in this simple and more complex environments (i.e. multiple output-multiple input technologies), see Diewert (1992).

[16] This reduced form directly comes from the translog production function with constant returns to scale hypothesis.

Previous studies on developed countries, such as Harrigan (1997,1999) and Griffith et al. (2004), consider only sectoral heterogeneity in slopes (i.e.χ_j). As I work also with developing countries, I improved such specification, allowing for country and sector heterogeneity in both intercepts and slopes, ξ_i, ξ_j and χ_{ij}. In particular, to avoid a major loss in data variability, due to many dummies, I grouped manufacturing sectors according Lall's taxonomy and I divided my sample into developed and developing countries, using World Bank definitions. The diagnostics employed strongly reject the null hypothesis of non-heterogeneity in both intercepts and slopes among different sectors and countries. More precisely, using panel data F-tests, I have detected, separately, intercept heterogeneity due to country and sector fixed effects. Through Chow type F-statistics, I have tested for sector and country heterogeneity, in both slope and intercepts.